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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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Substrate holder and device manufacturing method

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Substrate Holder and Device Manufacturing Method

The present invention relates to substrate holders, such as may be used in a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate; and
- a projection system for projecting the patterned beam onto a target portion of the substrate,

and to methods of manufacturing devices.

The term "patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such patterning means include:

- A mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.
- A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The

basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning means can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

- A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be

imaged onto a target portion (*e.g.* comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus — commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical

Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, incorporated herein by reference.

Silicon wafers used for manufacture of semiconductor devices come in standard sizes - 150mm, 200mm, 300mm (often referred to by their approximate size in inches - 6", 8" and 12") and the larger sizes are becoming increasingly popular since more devices can be manufactured on a single wafer, reducing the number wafer exchange steps and hence increasing throughput. Lithographic apparatus, and other apparatus used in semiconductor manufacture, are designed to work with these standard wafer sizes. In general, a lithographic apparatus will accept wafers of only one standard size. In spite of the general preference for larger wafer sizes, in some specialist fields it is desirable to be able to manufacture on wafers that are smaller and thinner than the standard sizes mentioned above. It is however uneconomic to manufacture or adapt lithographic apparatus to accommodate such small and thin wafers.

It is an object of the present invention to provide an adaptor that can hold a relatively small substrate and allow that wafer to be imaged on in a lithographic apparatus having a substrate table adapted to receive a larger substrate and/or to be processed in other substrate processing apparatus adapted for larger substrates.

The holder of the invention can be used with substrate such as silicon wafers as well as substrates of other non-magnetic materials.

This and other objects are achieved according to the invention in a substrate holder comprising a plate member having a first nominal size receivable by a lithographic apparatus, and a clamp for holding a substrate of a second nominal size, said second nominal size being smaller than said first nominal size.

By clamping the smaller substrate to a larger plate member, which is of a nominal size such that it can be processed by a standard lithographic apparatus, the smaller substrate can be processed by the lithographic apparatus, or other substrate processing apparatus, without modification thereof.

Preferably the plate member is substantially circular in plan and may have one or more flats or notches. The plate member may comprise a silicon wafer of standard dimensions to which the clamp is attached. Alternatively, the plate member may be made of Zerodur (™) or another non-magnetic material of low thermal expansivity.

The first nominal size is preferably 150mm, 200mm or 300mm or larger. The second nominal size may be 100mm or smaller. The nominal size in each case is the nominal diameter of the plate member or substrate, disregarding any flats or notches. The substrate and holder need not be round but may be of another shape, *e.g.* square. In that case, the nominal size is the largest dimension.

The plate member preferably has one or more positioning pins located such that when said substrate is abutted thereagainst, the substrate is located at a predetermined position and/or orientation on said plate member. Where the plate member is provided with one or more flats or notches and the holder is to be used with a substrate having one or more flats or notches, the positioning pins are preferably located such that the flat(s) or notch(es) of the substrate are in a predetermined, preferably corresponding, orientation to the flat(s) or notch(es) of the plate member.

The clamp preferably comprises a ring of magnetic material having an inner contour similar to but smaller than the outer contour of said substrate and a plurality of magnets fixed to said plate member. This arrangement ensures even forces are applied to the substrate, helping to keep the substrate flat whilst enabling the total thickness of the substrate holder to be kept small.

In a preferred embodiment, the plate member is provided with a fine burl pattern in the region on which said substrate is to be placed. The burl pattern prevents short range height variations in the clamped substrate.

According to a further aspect of the invention there is provided a device manufacturing method comprising the steps of:

- providing a substrate that is at least partially covered by a layer of radiation-sensitive material;
- providing a projection beam of radiation using a radiation system;
- using patterning means to endow the projection beam with a pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material,

characterized in that said step of providing a substrate comprises the sub-steps of:

- clamping said substrate to a plate member having a larger nominal size than said substrate; and
- loading said plate member having said substrate clamped thereto into said lithographic apparatus.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms “radiation” and “beam” are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (*e.g.* with a wavelength of 365, 248, 193, 157 or 126 nm) and EUV (extreme ultra-violet radiation, *e.g.* having a wavelength in the range 5-20 nm), as well as particle beams, such as ion beams or electron beams.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

Figure 1 depicts a lithographic projection apparatus in which embodiments of the invention may be used;

Figure 2 is an exploded view of a substrate holder according to an embodiment of the invention together with a substrate;

Figure 3 is a cross-sectional view of part of the substrate holder of Figure 2 with a substrate clamped therein;

Figure 4 is a plan view of a substrate showing the areas that can be imaged and measured when the substrate is held in the substrate holder of Figure 2; and

Figure 5 is a perspective view of a tool for mounting substrates onto the substrate holder of Figure 2.

In the Figures, corresponding reference symbols indicate corresponding parts.

Lithographic Apparatus

Figure 1 schematically depicts an exemplary lithographic projection apparatus in which embodiments of the invention can be used. The apparatus comprises:

- a radiation system Ex, IL, for supplying a projection beam PB of radiation (*e.g.* DUV radiation), which in this particular case also comprises a radiation source LA;
- a first object table (mask table) MT provided with a mask holder for holding a mask MA (*e.g.* a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;

- a projection system ("lens") PL (*e.g.* a refractive lens system) for imaging an irradiated portion of the mask MA onto a target portion C (*e.g.* comprising one or more dies) of the substrate W.

As here depicted, the apparatus is of a transmissive type (*e.g.* has a transmissive mask). However, in general, it may also be of a reflective type, for example (*e.g.* with a reflective mask). Alternatively, the apparatus may employ another kind of patterning means, such as a programmable mirror array of a type as referred to above.

The source LA (*e.g.* an excimer laser) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander Ex, for example. The illuminator IL may comprise adjusting means AM for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, *e.g.* after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1.

However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (*i.e.* a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

Such a lithographic apparatus is adapted for use with a substrate (wafer) of particular size, e.g. of nominal diameter 150mm, 200mm or 300mm, and shape, e.g. circular with one or two flats or a notch. In particular, the substrate table will be adapted to receive such a wafer and have a burl pattern of appropriate size and shape and locating pins to fit the notches or flats of the intended substrates. Where, as is common, the substrate is held on the substrate table by vacuum, the vacuum nozzles will cover the whole area of the substrate to ensure an even clamping force to avoid distorting the substrate. Also, the focal planes of the projection system and various sensors, such as alignment and level sensors are set at a particular level and the substrate table, which will generally have only a limited range of movement perpendicular to the plane of the substrate, is adapted to position the top surface of a substrate of given thickness at that particular level. If a substrate that is too thin or too thick is used, the substrate table may not be able to adjust its position sufficiently to put the top surface of the substrate in focus of the projection system and the various sensors.

<u>Embodiment 1</u>

Figure 2 is an exploded view of a substrate holder according to an embodiment of the present invention and a substrate. The substrate holder 10 comprise a plate member 11, to which are fixed positioning pins 12,13 and permanent magnets 14 which, together with clamp ring 15, form a clamp to hold substrate W firmly in place. A burl pattern 16 is provided to support the substrate W.

The substrate holder 10 is, by way of an example, for enabling a substrate of nominal diameter 100mm (4") and thickness 140μm to be processed in a lithographic projection apparatus, or other substrate processing device, that is adapted to handle substrates of nominal diameter 150mm (6") and thickness 500μm. As well as being dimensioned to fit the substrate table WT of the lithographic projection apparatus and present the substrate W at a suitable height, the substrate holder 10 ensures that the substrate W, which may be relatively flexible and highly curved due to its thinness, is kept flat for exposure. This is achieved by the fact that the substrate W is clamped by the clamp ring 15 around all, or substantially all, its periphery and by the burl pattern which is sufficiently fine to prevent short range height variations.

As can be more clearly seen in Figure 4, the substrate W has a primary flat F1 and a secondary flat F2. The positioning pins 12, 13 are located so that the flats F1, F2 abut against them to correctly locate the substrate W on the substrate holder 10 which in turn has a flat 17 for location of the substrate holder 10 on the substrate table WT. The clamp ring 15 may be provided with recesses in its underside to accommodate the positioning pins 12, 13 and/or the magnets 14.

It will be appreciated that the positioning pins 12, 13 and flats F1, F2, 17 do not have to ensure positioning of the substrate to within the overlay requirements of the lithographic process to be performed but rather need only locate the substrate W sufficiently that alignment markers provided on it are within the capture range of the alignment system of the lithographic apparatus. In other embodiments, the substrate W may have different a numbers and/or arrangement of flats and/or notches, whilst the lithographic apparatus may be adapted to receive a substrate with a different a numbers and/or arrangement of flats and/or notches. In that case, the positioning pins 12,13 on the substrate holder should be so located as to engage with whatever flats and notches are provided on the substrate in order to correctly position the substrate whilst the plate member 11 should have flats and or notches to engage whatever positioning means are

provided on the substrate table of the lithographic projection apparatus. The positioning pins 12, 13 locate the wafer W in the plane of the plate member 11 whilst the burl pattern locates it in the out of plane direction.

In this embodiment, the plate member 11 comprises a standard 150mm (6") silicon wafer, the location pins 12, 13 are of ferrite stainless steel and attached to the plate member 11 by an epoxy resin. The magnets 14 are NdFeB permanent magnets plated with NiP and the clamp ring is made of two layers of ferrite stainless steel. The use of two layers enables recesses to receive the magnets and/or positioning pins to be easily provided. Through-holes or cut-outs are made in the ring to form the lower layer only; this is much easier than forming blind shots in a thin ring. Also, one layer can be made of a steel selected for its magnetic properties and the other of a steel selected for strength.

As can be seen from Figure 3, the height T of the clamp ring 15 will obstruct the projection beam PB if it is attempted to project an image within a distance $d_1$of the inner periphery of the clamp ring. The exact value of distance S_I will depend on the thickness T and the numeric aperture (NA) of the projection lens PL, which determines the angle of the outermost rays of the projection beam. The width of the annulus that cannot be imaged on will be equal to S_I plus the maximum width, O_{max}, of the overlap between clamp ring 15 and wafer W. By suitable choice of T and O_{max}, the width of the unimigable portion of the substrate, which may be regarded as the shadow of the clamp ring, can be made comparable to the normal edge bead of 3mm. In a lithographic apparatus with on-axis leveling, the leveling sensor beam LS-B will have a shallower angle of inclination than the projection beam. This means that the shadow of the clamp ring to the leveling sensor beam LS-B, S_{LB}, will be wider and the vertical position of a larger portion of the wafer surface cannot be measured. This problem can be avoided by extrapolating from leveling measurements made in the inner portion of the substrate W. In Figure 4, the imigable area is shown cross-hatched and the boundary of the shadow of the level sensor beam is shown as a dashed line.

A loading tool 20 for loading wafers W onto the substrate holder 10 is shown in Figure 5. The loading tool has a platform 21 onto which the plate member 11 is placed, e.g. by a wafer handling robot (not shown) or manually. The platform 21 has a locating bar 22 which engages the flat 17 of the plate member 11 to ensure correct location thereof. Once the plate member 11 is correctly located the wafer W is placed onto the burl

pattern and against the positioning pins. Again this can be performed by a wafer handling robot or manually. Meanwhile, the clamp ring 15 is held on an annular vacuum chuck 23 by vacuum. the annular chuck 23 has locator holes 24 on projections that engage with locator pins 25 provided on platform 21 when the annular chuck 23 is inverted and lowered onto the platform 21 so that the clamp ring is correctly located over the substrate W. The vacuum is then released and the annular chuck removed, leaving the clamp ring held by magnets 14 to the plate member 11. The substrate holder 11 and held substrate W can then be delivered to the lithographic apparatus, e.g. by wafer handling robot.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.

CLAIMS:

1. A substrate holder comprising a plate member having a first nominal size receivable by a lithographic apparatus, and a clamp for holding a substrate of a second nominal size, said second nominal size being smaller than said first nominal size.

2. A substrate holder according to claim 1 wherein said plate member comprises a silicon wafer of standard nominal dimensions to which the clamp is attached.

3. A substrate member according to claim 1 or 2 wherein said plate member is substantially circular in plan and optionally has one or more flats or notches.

4. A substrate holder according to claim 3 wherein said first nominal size is 150mm, 200mm or 300mm or larger and said second nominal size is 100mm or smaller.

5. A substrate holder according to claim 1, 2, 3 or 4, wherein said plate member has one or more positioning pins located such that when said substrate is abutted thereagainst, the substrate is located at a predetermined position and/or orientation on said plate member.

6. A substrate holder with according to claim 5 for use a substrate having one or more flats or notches, wherein said plate member is provided with one or more flats or notches and said positioning pins are located such that the flat(s) or notch(es) of the substrate are in a predetermined, preferably corresponding, orientation to the flat(s) or notch(es) of the plate member.

7. A substrate holder according to any one of the preceding claims wherein said clamp comprises a ring of magnetic material having an inner contour similar to but smaller than the outer contour of said substrate and a plurality of magnets fixed to said plate member.

8. A substrate holder according to any one of the preceding claims wherein said plate member is provided with a fine burl pattern in the region on which said substrate is to be placed.

9. A device manufacturing method comprising the steps of:

- providing a substrate that is at least partially covered by a layer of radiation-sensitive material;
- providing a projection beam of radiation using a radiation system;
- using patterning means to endow the projection beam with a pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material,

characterized in that said step of providing a substrate comprises the sub-steps of:

- clamping said substrate to a plate member having a larger nominal size than said substrate; and
- loading said plate member having said substrate clamped thereto into said lithographic apparatus.

ABSTRACT

Substrate Holder and Device Manufacturing Method

A substrate holder to adapt a small wafer to a wafer table of a lithographic apparatus adapted to receive a larger wafer comprises a larger silicon wafer with a burl pattern on which the small wafer is to be placed, positioning pins to locate the small wafer and a clamp formed by a clamp ring and magnets attached to the larger wafer.

Fig. 2

Fig. 1

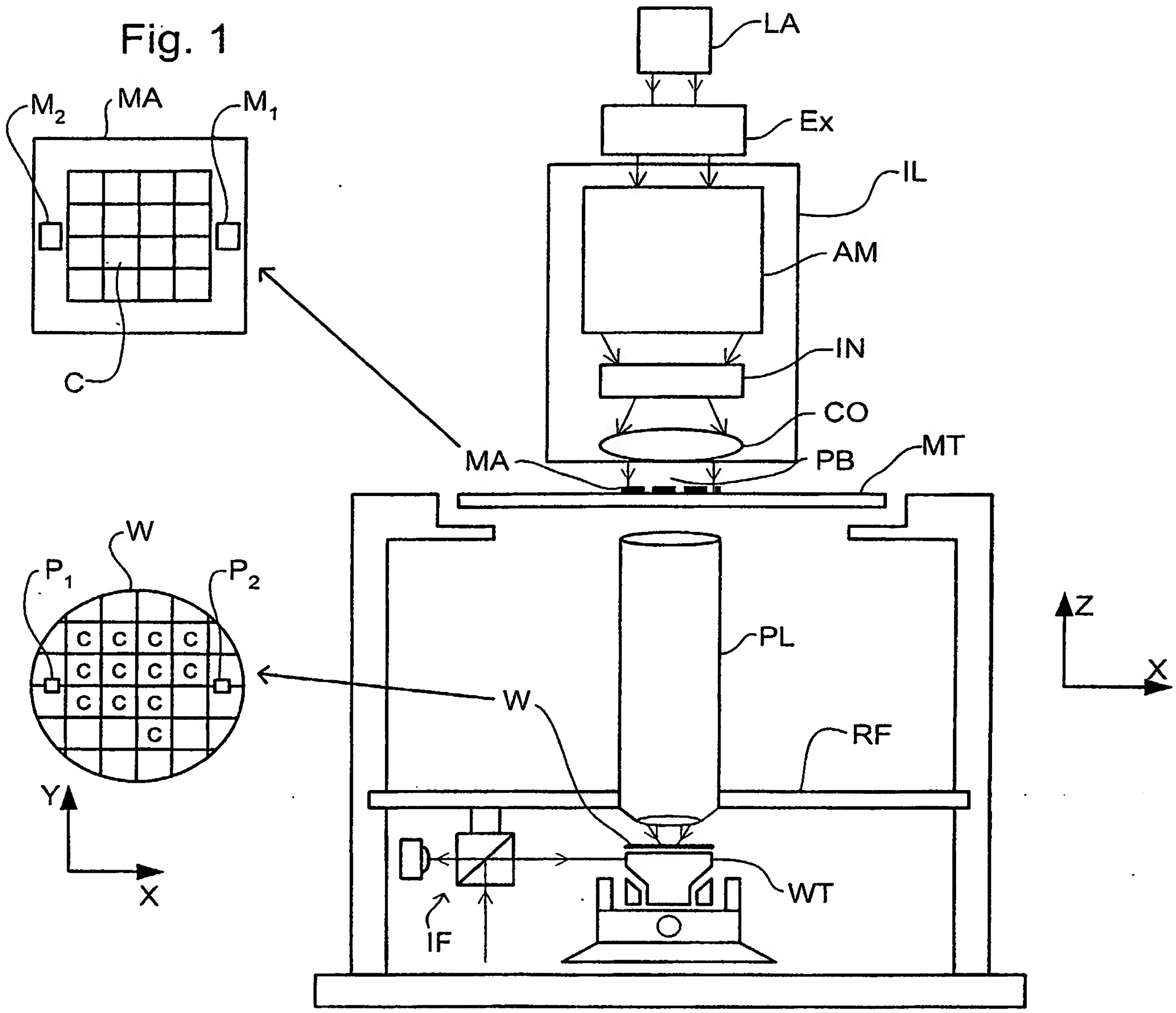
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Fig. 2

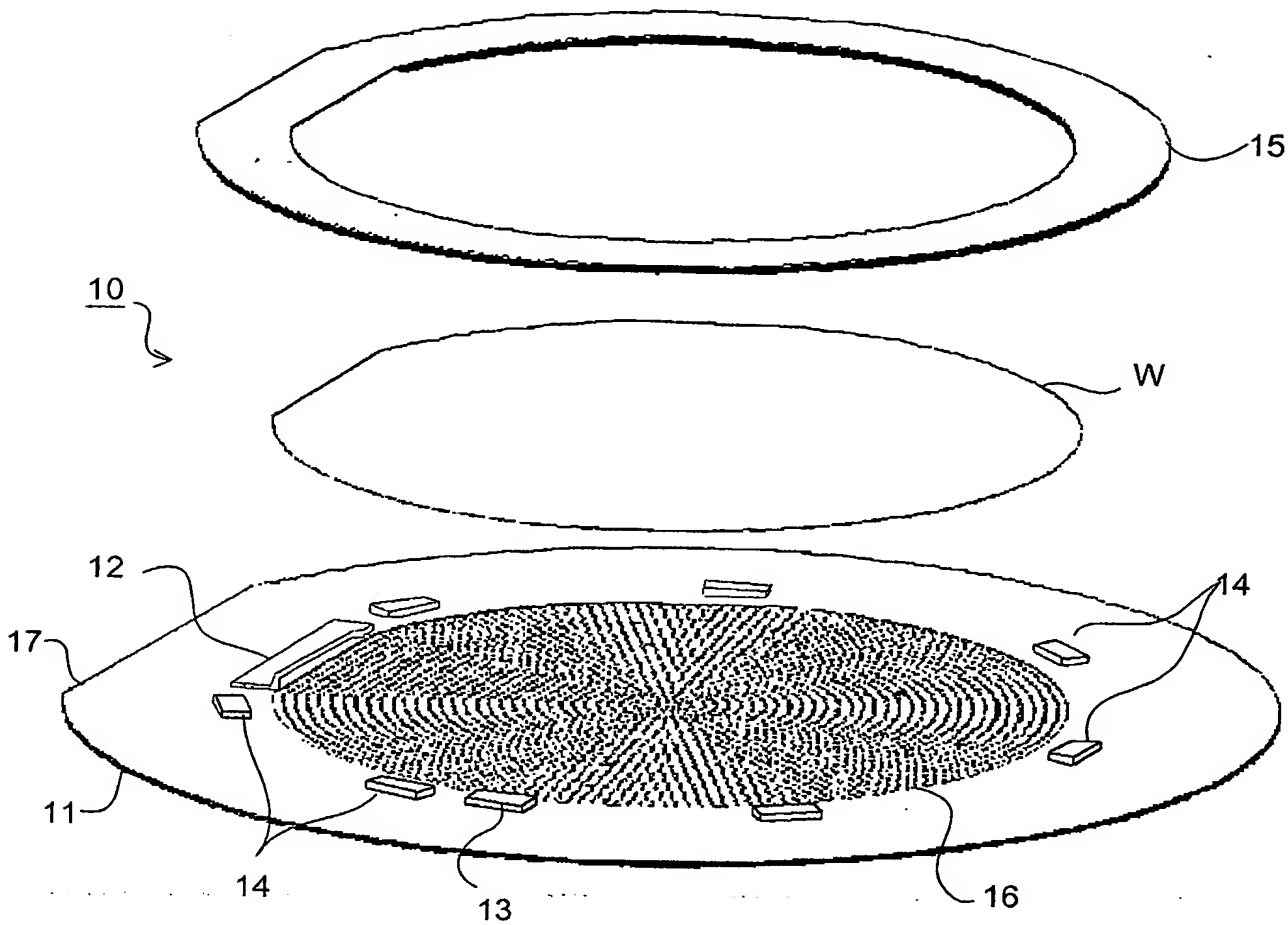

Fig. 3

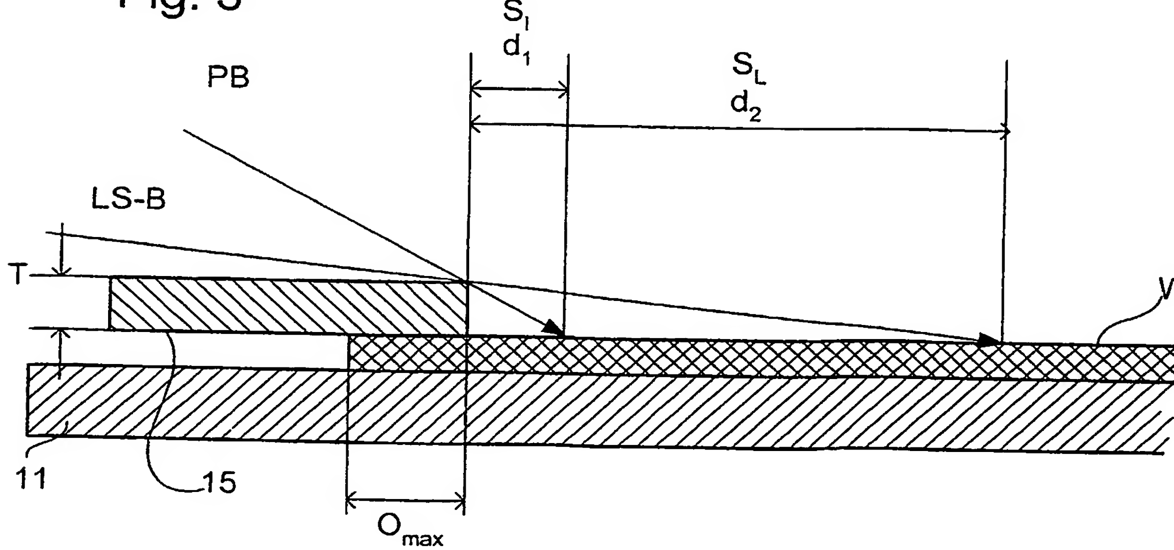

Fig. 4

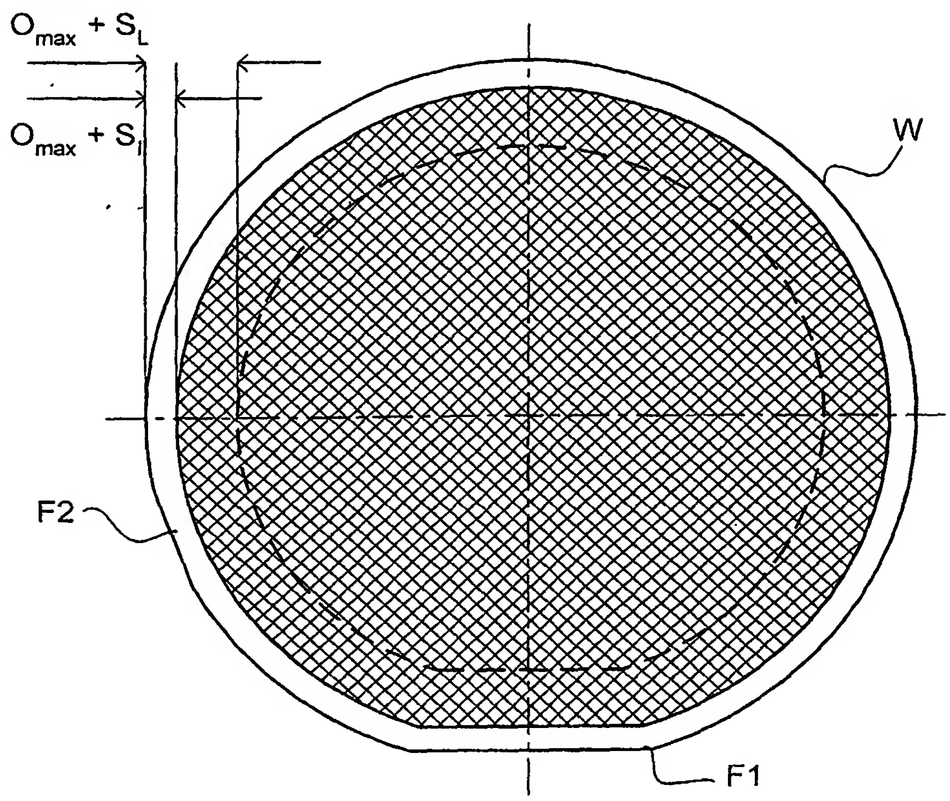

Fig. 5